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Scientific Collaboration Networks of Mathematicians from the Former Soviet Union in the Global South

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Abstract

This article explores the scientific collaboration networks of mathematicians from the Former USSR in the Global South, the case of Mexico. We used the Social Network Analysis (ARS) macro perspective focusing on the collaboration that scientists have had since they arrived in Mexico. We also use the public Database of the American Mathematical Society (MathScience) from which collaborations are reported in articles, chapters of books and proceedings published, and the Pajek software as tools for the analysis and visualization of social networks. The results of the study show the heterogeneity of scientific network collaboration nationally, regionally and internationally, and brings to debate some considerations that have not been taken into account when contexts and spaces do not correspond to traditional and binary "South-North" highly skilled migration

Keywords: Scientific Collaboration Networks, Mathematicians, Ex-USSR, Global South, Mexico

1. Introduction

In the 1990s, new approaches to the study of highly-skilled international migrations were no longer anchored in brain drain analysis and, in principle, neither in the brain gain of a single (individual or collective) participant. Rather, they focused on the links between leaving scientists and their remaining peers, and on the way in which the new dynamics that are established allow to maintain an interaction and exchange between different actors. Since then the interpretative scheme of the 1950s and 1960s on the South to North brain drain, and its intermittent re-emergence in the two subsequent decades, began to decline. During the 1990s, it was frequently pursued "to recover the national capacities that had emigrated, but without aiming as the main goal to the return to the country of the capable ones" (Charum 1998, p. 138), through the links that were generated between the migrant communities with their communities of origin, a scheme known as Diaspora Knowledge Networks (DKN). A DKN was an attractive interpretative scheme on qualified international migration because it supported the idea of a connection without factoring in losses; the goal was to win-win. China, Korea and India were classic examples of the phenomenon.

However, the empirical data we have collected on the collaborative networks of a group of immigrant mathematicians from the Ex-USSR in the Global South provided elements of analysis that show differences with this scheme, approaching (but also distancing from) the idea of Caroline Wagner (2008, p. 48), which highlights science as a domain of competence circulation in a more individualized world in terms of mobility decisions on the basis of the construction of interpersonal links. The author represents that world as a continuous opportunity for connection. At the time Soviet scientists emigrated from their countries of origin, there was no scientific community in their home country with whom they could collaborate (both for lack of researchers and for scarce financial and infrastructure resources locally).

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In the 1990s, when scientists settled in their new academic spaces, the idea of serving the country of origin (in the "win-win" DKN formula) was no longer so important, but rather to emigrate and perhaps help other colleagues to leave the 'shipwreck' to continue working in science in other spaces that allowed their individual development. In Wagner's words, when the former USSR disintegrated, scientists "entered the global system, creating new links with colleagues through scientific collaborative projects around the world" (2008, p. 60). From our standpoint, and here we distance ourselves from Wagner, global scientific collaborations are built within the social fabric prevalent in the local context where immigrant scientists work. For the present case, we agree that the world appears as a horizon of possibility of landing for the scientists from the former USSR but we also maintain that Mexico was/is one of the local anchors of work and life from where the scientific identities and hybrid life experiences that intertwine global scientific collaborations are constructed and reconstructed. In that sense, we move away from Wagner's purely globalist vision and move closer to the idea of the Global South mosaic (Vessuri, 2017).

Mexico, followed by Brazil, had already been identified as one of the main Latin American academic spaces where the scientists from that region had been inserted (Izquierdo, 2015). From the areas of knowledge, scientists from the basic sciences were chosen because in the 1990s it was pointed out (Simanovsky, Strepetova and Naido, 1996) that of the large group of skilled migrants from the former Soviet Union, that area was the one that integrated a large group of migrants, coinciding with the data collected for the Mexican case, which concerns us here.

In this article, we present the exploratory study of former Soviet mathematicians immigrated to Mexico, with particular reference to the networks of scientific collaboration of 17 mathematicians whose job as researchers of public universities in Mexico. Our research questions were two: What is the meaning and value that the DKN model and the notion of new invisible college hold when actors come and are inserted in contexts, spaces and directions different from the traditional and binary (imaginary, symbolic or real) "South-North" context? What kind of collaborative links do scientific communities construct that at some point in history were considered as variants within the "hegemonic" currents in the construction of knowledge and which in recent decades, fundamentally for political and economic reasons, ceased to be a center of attraction and became part of the international flows of skills located in developing countries? In the study, we used the macro perspective of the Social Network Analysis (SNA) (Marin and Wellman, 2009), and the public database of the American Mathematical Society (MathScience) that reports collaboration on articles, chapters and proceedings published in co-authorship, using the Pajek software as a tool for the analysis and visualization of social networks.

2. Diaspora Knowledge Networks (DKN) and Networks of Invisible Colleges

In the 1990s, mobility issues and the circulation of "brains" in the society of knowledge were very relevant. In that decade, it was said that in a globalized world such as ours, scientists in continuous movement should no longer represent a loss, even if they did not physically return to their countries of origin because there would always be the possibility of building links, back and forth, for the return of ideas and serving as bridges for students and colleagues between their countries of origin and their countries of residence (Meyer and Brown, 1999). The notion of networks became more important in studies of international migration since the 1980s when combined with the notions of social networks and social capital (Massey et al., 1987). And in the 1990s the idea of networks for the study of migrations qualified through the DKN scheme, which was based on the creation of links or connections between the personnel working abroad with their peers in their country of origin, without the permanent or temporary physical return of the former, was systematically retaken.

In 1990, the subject of skilled migration emerged from the neglect in which it had been left in the 1980s. But this time it was driven by the discourse being promoted in some international organizations. The arguments that have been defended by United Nations Educational, Scientific and Cultural Organization (UNESCO), for example, have to do with the construction of knowledge societies thought to be "a powerful vector in the fight against poverty" (UNESCO 2005, p. 20). Others, such as the Organization for Economic Co-operation and Development (OECD), the World Bank (WB) and the International Monetary Fund (IMF), have also signaled their agreement and support on this issue, specifying actions and also funding studies and initiatives on the subject of DKN, mobility and skilled migration (Carrington and Detragiache, 1998; Mahroum, 1999; Lou and Wang, 2002; Gokhberg and Nekipelova, 2002; Adams, 2003; Meyer and Wattiaux, 2006).

From this interpretive scheme, it was stated that distance-cooperation had always existed, the difference being that they were sporadic, exceptional and limited connections, while since the 1990s they have been more frequently transformed into systematic, dense and multiple nexuses (Meyer and Brown, 1999) enabling important results for the science and technology systems of countries where the diaspora occurs (Charum, 1998).

Five levels of expatriate knowledge networks were identified: students, local expatriate associations, the assistance of experts such as the Transfer of Knowledge through Expatriate Nationals (TOKTEN) program, the developing networks of the intellectual/scientific diasporas and the consolidated ones (Brown, 2000). In the first census of Scientific Diaspora Knowledge Networks (Meyer and Brown, 1999) carried out in the 1990s, these authors (Meyer and Brown, 1991) placed 41 networks distributed in 30 countries. Years later, other censuses were carried out corroborating the increase of the networks of knowledge in the world. In 2003, 106 networks created exclusively in developing countries were detected (Barré et al., 2003 in Meyer and Mattiaux, 2006); a year later 20 more were located (Lowell and Gerova, 2004) and finally in the census of 2005, a total of 158 networks were found (Meyer and Mattiaux, 2006). According to the authors, in almost five years the ties of different communities in the world had tripled. The most consolidated networks are the Chinese and Hindu intellectual/scientific diasporas located in the United States (Devane, 2006; Biao, 2007), which have been characterized by strengthening scientific ties in both engineering and trade with their countries of origin. And it must be said also that they have based those links on the interest of the American institutions for which they work and from which they obtain funding. The objectives pursued by networks of intellectuals and scientists have to do with the establishment of communication, exchange, publication and development of scientific and educational projects among scientists. Other types of network also pursue issues such as the promotion of social development, cultural dissemination activities, and trade.

In Latin America, the development of knowledge networks for Latin American expatriates in countries such as the United States and France shows several results. In 1993, the Colombian Network of Researchers and Engineers Abroad (Red Caldas [for its Spanish acronym]) was created with support from the Colombian government. This Network was basically created to stimulate forms of relationship and institutional mechanisms that allowed established researchers working abroad to collaborate in science and technology development activities with their country. Although the network was initiated with great enthusiasm, it was eventually disintegrated (Chaparro et al., 2006). In addition to Colombia, other like Argentina, Chile and Venezuela have also entered the DKN (De la Vega and Vessuri, 2008). In Mexico this is still seen as a little-explored terrain. The actions implemented by the government have been biased because they have focused on highlighting the benefits of networks in the areas of business and commerce, i.e. they have put the interest of the market at the center, forgetting their original objectives. It should also be said that diasporas are often due to deep disagreements with existing governments, in which cases networks are built not only without the intermediation of governments, but often against them, as was the case of the Argentine academic exile (Vessuri, 1994).

Recently, through different case studies, there have been some clues to what could be an effective “win-win” scheme (the host country with the diaspora wins and also does so the origin country with the links it gains). For example, the cases of Colombians, Indians and South Africans in Switzerland (Tejada, 2013), of the Chinese in the United States (Chen and Koyama, 2013), of the networks woven between migrant scientists with their peers in their countries of origin, especially those who, in addition to being migrants, had previous international experience because they did postgraduate or postdoctoral studies outside their countries of origin (Scellato et al., 2015); and the efforts of some governments to promote and support diaspora networks with different resources as a strategy to make a profit in national economic development (Larner, 2015). The interesting analysis about this last study is the conceptualization and treatment of these strategies as “networks of global knowledge”, as if this implies a link of the whole world, when it only refers to a pair of countries, that is to say, developed countries.

Certainly, important efforts have been made to show that the development of such links is or may be promising, but the bulk of these studies has only been observed through the lenses of international mobility and migrations labeled South-North. That is to say, with qualified personnel from developing countries migrating to developed countries, in a cycle that differed from the previous historical trend, when there was an important migration of scientists from the most industrialized countries to the colonies or new independent countries, first as travelers, collectors and expedition members, but also as teachers and instructors of knowledge institutions since the eighteenth century. This was a very popular form of scientific cooperation known as the “transfer of knowledge and skills” from North to South for development (Vessuri, 1994).

Links between researchers that extend beyond particular institutions and places have been known as "invisible colleges". The term has its origins in 1645 with chemist Robert Boyle, who used it to describe the interactions of a small group of natural philosophers who met informally and differently from other groups that were integrated into more visible and formal colleges such as Wadham and Gresham Colleges. Later that group was formally organized to form the Royal Society of London (De Solla, 1963; Wagner, 2008). Derek de Solla Price researched scientific collaboration networks in the 1960s by using articles and citations for the notion of invisible colleges (De Solla, 1963). A decade later, Diane Crane studied invisible colleges through the collaboration and dissemination of knowledge in international scientific communities (Crane, 1972). After other three decades had passed, Caroline Wagner renewed the debate on scientific collaboration through the 'new' invisible colleges, showing the growth of global collaborative networks, arguing that "these links are the invisible basis on which global scientific communities operate" (Wagner, 2008: 27).

According to the author, since 1990 the structure of science has changed and provides five ways of how this change can be perceived. Scientific collaboration networks have spread globally and are no longer addressed by a particular government or individual. They are often open, adaptive and changing. They are emerging because science is an ecosystem that develops with its own dynamics rather than a corporation. In that sense, it is the scientists themselves who choose the people with whom they want to work with and also choose the tools that can help them advance their work. Another change is the growing circulation of "brains". Wagner believes that scientists have the freedom to migrate where it suits them best and to insert themselves in the spaces where they can best develop their abilities. Another change is the concentration of the scientific activity that the author also calls as geographical neighborhood. And finally, more and more the distribution of scientific tasks happens throughout the world without the need to be in the same place through the use of the Internet (Wagner, 2008).

These changes have also been accompanied by a global competence market and also by the type of funding for the development of science. We moved from the support and protection of governments directing the research projects, to the international country to country (between nation states) collaboration, and now to global collaboration. This is a situation that, at least in the Mexican case we are presenting, does not occur. The government supports the funding of science and thus directs the lines of research supported in the funding of national projects. The author argues that at present "it is the researchers, not the government, who set the rules. There is global collaboration; researchers are free to work on common global problems, regardless of where they are geographically located. Global science grows not because governments are promoting it but because it serves the needs of the global community and for the development of one's own knowledge" (p. 31).

In our study there appears to be a combination of what is described by Wagner (2008), with something different. In the Mexican case two logics are at work at the same time. On the one hand, there are the "free agents" who aspire to some work-space, and on the other, there is the Mexican government that, recognizing the space of global competition, developed a policy with a global logic taking advantage of the implosion of another nation-state, for capturing the individualized quest of former Soviet scientists who were available in a global competency market. In the present case, the Mexican nation-state not only did not cease to exist but also promoted local policies to attract highly-skilled personnel. In 1991, the government, through the National Council on Science and Technology (CONACYT [for its Spanish acronym]), implemented the Program for the Support of Science in Mexico (PACIME [for its Spanish acronym]), whose main objective was to "significantly increase the development and diffusion of scientific activity of the country, increasing in number and in quality the national roster of researchers" (PACIME, 1991, p. 19). One of the subprograms financed through PACIME was the Patrimonial Chairs. In that subprogram, it was proposed to hire "visiting foreign professors who are interested in teaching and research activities in a Mexican institution for one to two years" (PACIME, 1991, p. 16). Many of those who came to the country not only renewed their stay but were permanently established in Mexico, as was the case of the group of scientists from the former USSR in this study. The Subprogram was operational from 1991 to 2002, during which time a little more than 1000 foreign scientists came from different parts of the world to the country, 261 of that number corresponded to scientists from the former USSR. In the study of the networks of scientific collaboration of the mathematicians of the former USSR immigrants in Mexico, we mainly return to Wagner's notion when she states that "networks are interconnected relations of actors" (p. 36) and that their most important feature is that they are self-organized, i.e. the scientists organize and reorganize themselves dynamically and flexibly, "networks constitute invisible colleges of researchers who collaborate not because they have to but because they have to offer skills and knowledge to others.

These collaborations are carried out across borders through virtual ties, structures that create knowledge cannot be limited to national boundaries, as it was in the late World War II and in the Cold War era" (Wagner, 2008). One of the author's premises is that the importance of actors and their role as "free agents" permeates the construction of networks of scientific collaboration, where actors' affiliations are no longer based on national institutions but on the interests and development of global knowledge (p.64). However, since the sixties, elements of analysis on scientific mobility from Latin American spaces (Horowitz, 1962; Oteiza, 1969; Slemenson, 1970) were already available and in the 1990s new models such as the circulation of skills intensified (Vessuri, 1994) suggesting other possible lines of interpretation from the Global South.

3. Scientific Migrants From the Former USSR

The migration of scientists from the Ex-USSR in the 1990s covered almost all continents (Strepetova, 1995). Some authors (Piskunov and Len'šin, 1992; Kouznetsova, 1996; Gokhberg and Nekipelova, 2002) argue that these migratory flows were mainly directed at the United States, Israel and Germany, but also include countries such as Great Britain, Australia, Canada, New Zealand, France, Italy and Japan, as well as the Mediterranean and Scandinavian countries (UNESCO 1994; Simanovsky et al., 1996; Rybakovsky and Ryazantsev, 2005; Latova and Savinkov, 2012) as well as some Latin American countries (Izquierdo, 2011), among other destinations.

So far, it has not been possible to quantify the emigration of scientists from the former Soviet Union, especially since the data that can be collected on them are very different between the sources and the parameters used to quantify the phenomenon. In the texts that were consulted, there were figures that refer to "Russian" scientists, but that did not specify if other republics that conformed to the former Soviet Union were or were not considered in that designation. The Ukrainians and Russians are two of the most documented cases. In 1990 the Ukraine had 349 100 scientists and employees working in universities; 6 100 doctors of science and 50 400 doctoral candidates (UNESCO, 1994). It was estimated that from 1988 to 1992, 219 500 scientists and engineers had emigrated. Just for the period of 1990-1992, 159 doctors of science and doctoral candidates had emigrated from institutes belonging to the Academy of Sciences of that country and 400 researchers with university degrees had gone to different countries to work in temporary jobs, such as Israel, the United States, France, Great Britain, and Eastern European countries, among others (UNESCO, 1994).

In the case of Russia, it was stated that in 1991 it had 878 482 scientists engaged in research and technological development and four years later it had 518 690. In 1993, a total of 64 593 highly qualified Russian emigrants were identified in countries such as Germany, Israel, the United States, Greece, Finland, Bulgaria, Canada, Australia, Poland, Sweden, Hungary, the Czech Republic, France and others (Strepetova, 1995). Between 1989 and 2000, over 20 000 academics who were employed as researchers and research assistants had emigrated from Russia as well as other 30 000 specialists working abroad on temporary contracts (Sadovnichy and Kozlov, 2005). With regard to the countries and the number of scientists who emigrated, it was reported that 30 000 Russian scientists worked in Israel and the United States, more than 4,000 in Germany, 600 in France and 95 in Korea (Orlova et al., 1994)

To all this numerical diversity, we should first add the uncertainty about whom to consider as highly qualified professionals from that region (Parkhomenko, 2006). This study will focus especially on scientists. We should take into consideration not only the quantification of external and permanent migration, but also the internal migration – that is, scientists who changed their work field to banking, airlines, computing, tourism and services in general, as well as those who developed their own businesses–, and highly qualified mobility that includes temporary contracts, short research visits, teaching and academic training abroad.

4. Insertion Into Mexican Universities

In the nineties and the first decade of the second millennium, scientists and artists from the former Soviet Union migrated to Mexico. In the case of the scientists, it was stated (Kudimov, 1992; Izquierdo, 2011) that physicists, mathematicians and chemists came to work in Mexican universities, that more than 500 highly-skilled workers from the former Soviet bloc worked within the national territory; and it was reported that 227 professionals from different areas resided in the country, both in the center and in the hinterland of Mexican republic. Under the subprogram of Patrimonial Chairs, several groups of scientists were reported working in Mexico; 144 scientists were identified arriving to that subprogram and staying to live *permanently* in the country, 79 of them in the basic sciences.

There are other groups of scientists from that region who came to the country and decided to stay but they came instead through agreements directly promoted by Higher Education Institutions (HEIs) and through invitations from their Mexican colleagues and compatriots who had arrived with the Chairs subprogram years earlier (Izquierdo, 2015).

Like the migration of scientists, the collapse of the scientific apparatus in the USSR did not happen from one day to the next, this was a process that began long before. Economic problems began to become more prominent since the 1970s, and in the 1980s scientists began to feel the toll but their migration had its most intense momentum, also known as "the second wave of the brain drain, during the years of 1992-1993" (Graham and Dezhina, 2008, p. 24), a few years after the disintegration of the Soviet Union as a country. In general, the reasons for the migration of scientists from that region have been described as being of three types: political, national and economic (Shevtsova, 1992). Especially the latter, was the reason that some authors (Gokhberg and Nekipelova, 2002) detected as predominant for the migration wave in the nineties. Issues such as the reduction of funding for science, the low economic growth of researchers, the dismantling of lab infrastructure and higher education and scientific institutions, the loss of prestige of intellectual work, the lack of opportunities to develop scientific potential, among others, were the causes that integrated the so-called internal and external migration of scientists (Moody, 1996; Ivakhnyuk, 2006; Genov, 2007).

The USSR had its highest technological and scientific development from the 1930s to the 1960s, with three outstanding characteristics in that period: the centralized administration system of higher education institutions and the scientific system; the industrialization of the country and scientific-military development, the latter especially after the Second World War and finally the beginning of the opening in certain disciplines and some ideological liberalization. In the 1970s, the economic system based on centralized planning showed the first signs of crisis (Kojevnikov, 2004). At the end of the eighties, the Soviet government began to change the orientation of science, especially in connection with military development. Soviet elites began to identify science as something "useless". Instead, privatization began to be used to maintain the belief in a better future. In this way reforms and changes in the structure of the Soviet economic system began, with the transformation of a centrally planned economy into a free market, and continuing with the privatization of industry (Rabkin and Mirskaya, 1993). The funding of science took second place, laboratories and the development of research projects of scientists were no longer a priority. In this context, scientists began to emigrate in the 1990s.

Scientists reported that some made several attempts to go to the United States, and other countries before Mexico. But in these cases it turned out that either they were not accepted or did not receive a response to their letters, or while they were waiting for a reply, they first received the invitation to work in Mexico. The invitation was accompanied, in several cases, by the plane ticket and once they arrived in the country, some of those responsible for their stay here or who had invited them, lent them money while they received their first pay check from the universities where they had arrived to work. Mexico not only represented an "opportunity", in several cases, the only "opportunity" at the time for scientists to leave the region, it also gave them the possibility of jumping to their desired destiny, to serve as an academic bridge in case they could go to work in the United States or Canada, as was the idea of several of them, once they arrived in Mexico (Izquierdo, 2015).

5. Scientific Collaboration Networks of Mathematicians in/from Mexican Universities

Upon their arrival to the country, some of the mathematicians already had scientific collaborations with the academic community in Mexico and in a couple of cases at an international level. These ties strengthened over the years to achieve what can now be classified as a robust and diversified network of scientific collaboration, active and flexible, with several nodes and ties in Mexico as well as at a regional and international level. The first year for the analysis of collaborations (articles, book chapters and proceedings) was 1992, the year in which the first mathematician in the study arrived in Mexico, until 2014. In those years, mathematicians have collaborated with colleagues and students who are working in 27 countries (including Mexico), distributed in 4 continents. The countries are as follows: Brazil, Colombia, United States, Canada, Russia, Ukraine, Hungary, Poland, the Czech Republic, Azerbaijan, Germany, Spain, Italy, Sweden, Finland, Holland, Belgium, France, Great Britain, China (Taiwan), Japan, Indonesia, Israel, Turkey and Australia. In the article, we integrate and identify the 27 countries with 8 colors, which can be seen in the following graph (**Figure 1**), as follows:

Mathematicians In the study, actors or egos, (red), their collaborators or alteri in Mexico (black), collaborators in Latin America (white), North America (pink), collaborators in their countries of origin (green), in the European Union (yellow), in Asia and Southeast Asia (dark blue), and others Integrated by Australia, Israel and Turkey (light blue).

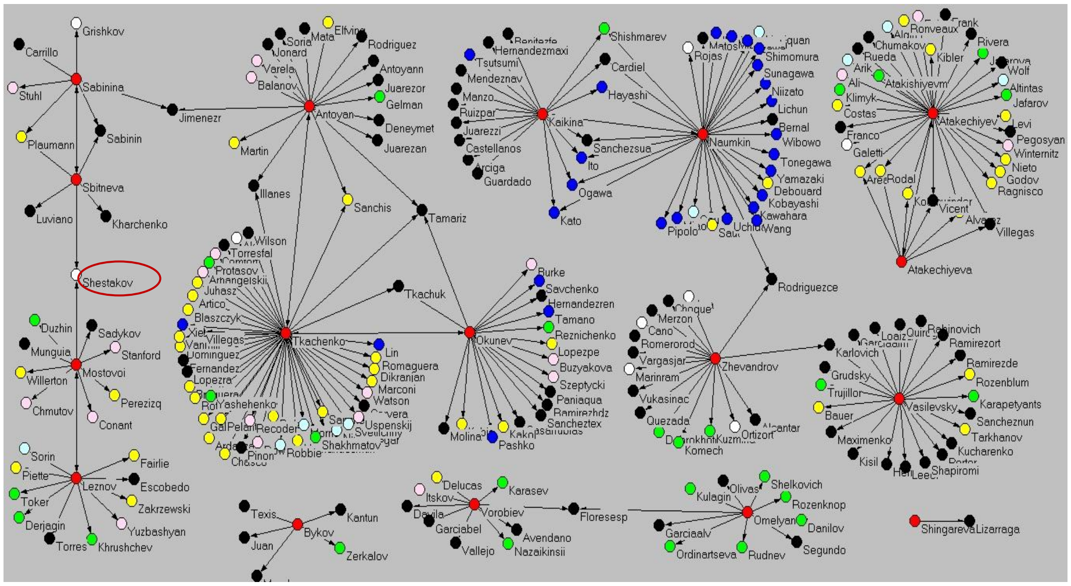

Figure 1 The Mathematicians and Their Scientific Collaborations in the World

We found that the mathematicians have collaborations with 232 colleagues, among whom the first place is held by their collaborators working in Mexican institutions (93), followed by institutions belonging to the European Union (46) and in third place, collaborators in institutions in their country of origin (28). This result contrasts with the idea of the DKN model when it is mentioned that the country of origin of the skilled migrants gains (as does the country of destination) in the case of scientific collaborations. This point is important if we pay attention to the directionality of migrations, in this case it is not a "traditional" highly qualified migration of the so-called South-North type. Another point of divergence relative to the so-called South-North migrations is that for the case of the 17 study subjects, their first scientific spaces of collaboration are not those located in the United States and Canada. In the group of mathematicians reported, the United States and Canada, -countries in North America (20)-, were surpassed by the country of destination itself, Mexico, the European Union, the countries of origin of the mathematicians and by Asia (26). Although the difference is small, we would like to point out that for this particular case, Asia appears as an emerging region that deserves attention in the reconfiguration of the centers from which knowledge is produced, developed and disseminated, and its connection with the scientific spaces that have been considered as the "periphery" of knowledge, as is the case of Mexico.

The links that mathematicians had, and are currently developing, in Latin America (represented by the white circle) deserve further analysis. This subject will be dealt with in another article. From the analysis of social networks, the collaborations in this region does not seem significant in comparison with those of the European Union, which after Mexico is the second geographic space where links are reported. Total collaborations in the Latin American region were 9, represented by 10 publications of mathematicians located in 6 universities in Brazil and Colombia. However, the analysis of the interviews drew attention to the network of scientific collaboration that is being woven between mathematicians of the former USSR in Mexico and Brazil, which has incorporated new actors (both researchers and graduate students and postdoctoral students from Russia, Ukraine, Latin America and other parts of the world), as well as other dynamics of collaboration through research-stays, workshops, schools of mathematics and seminars promoted and supported especially by a node in Brazil (red ellipse). Although in the present graph, the activity and dynamics of the network's structure is not easily appreciated, in recent approaches that we have carried out in fieldwork it seems that this new collaboration scheme is a key actor in order to understand the links, movements and dynamics of knowledge construction in mathematics in the Global South. This last point adds to the debate on the Wagnerian globalist position, from which, as we said at the beginning of the text, we take some distance.

We point out another issue of analysis that has to do with the collaborations that mathematicians have with their peers and students through institutions. It was corroborated that the universities where they maintain their collaborations are those located in the centralized knowledge space in the country, that is, the National Autonomous University of Mexico (UNAM [for its Spanish acronym]) –where a very important Mexican scientist was identified by the number of connections with three mathematicians located in universities of the country having a high prestige in the national development of basic sciences–, the Center for Research and Advanced Studies of the National Polytechnic Institute, and the Autonomous Metropolitan University, in that order. But the collaborative activity at the Technological Institute of Morelia that one of the mathematicians had with her former students caught our attention, because total numbers displaced by two points, the Meritorious Autonomous University of Puebla, and the University of Sonora (**Figure 2**. Triangle: students-collaborators. Square: co-workers. Circle: mathematicians of study).

It should be mentioned that we found four universities in the "periphery" of science in Mexico, whose indexes in the production of knowledge supported by the National Council of Science and Technology regarding the number of members of the National System of Researchers do not stand out by their numbers, but that in this study they do appear, these are the Autonomous Juarez University of Tabasco, the Autonomous University of Guerrero, the Juarez University of the State of Durango, and the University of the Isthmus of Oaxaca.

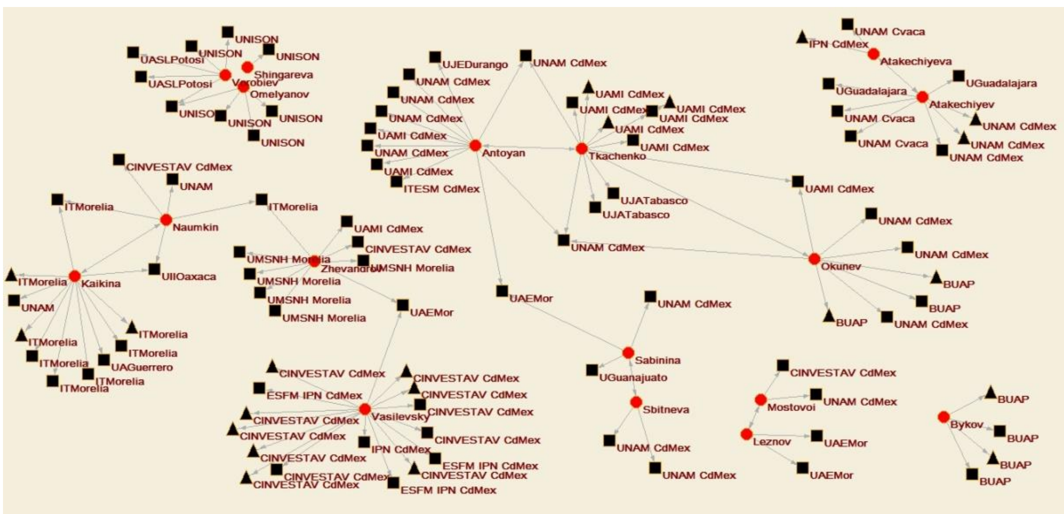

Figure 2 The Mathematicians and Their Scientific Collaborations in Mexico

We consider relevant to put in the spotlight the links that highly skilled immigrants weave with the scientists and teachers of the host country that work in peripheral spaces. In the case study, at least five collaborations that are developed in the scientific "periphery" of Mexico stand out, as mentioned in the previous section. These nodes should be tracked and monitored in order to provide other elements that would allow to highlight the collaborations with researchers in "peripheral spaces" of knowledge in the host country by the qualified international immigrants. The significance of this could lie, for instance, in the collaborations between the mathematicians and their students in Mexico. This could be a way of knowing the incidence of a public policy (the subprogram of patrimonial chairs) that had among its objectives the international attraction of scientists to the country in order to consolidate certain areas of research by strengthening the training of young researchers. In the present case, it was found that 9 of the 17 mathematicians participating in the study are members of the National System of Researchers (SNI [for its Spanish acronym]), level III, which, according to the rules of the System itself, means that they have established research groups actively involved in the training of human resources in science in Mexico. However, it was found that, according to the data that we obtained for the realization of the last graph, several of these mathematicians did not report publications in collaboration with their students. We consider it important in future research to trace these links not only to understand the structures of scientific collaboration networks in and from Mexico but also to know the impact of investments and stakes of the federal government when implementing actions to attract highly-skilled personnel (either national or foreign) to the Mexican public Higher Education Institutions (HEIs).

6. Conclusions

The literature reviewed showed the DKN model and the notion of new invisible college are traversed by a reading of the partial social reality that impacts on the construction of knowledge about mobility and scientific migration where the Global South is relegated. Focusing on the group of immigrant scientists from the former USSR in Mexico, our objective was to showcase other origins and destinations that have usually been obscured in the global geography of skilled migration. The DKN model and the notion of new invisible college are important interpretive schemes that allow an orientation in the study of collaboration networks and knowledge mobility, but they do not suffice to understand the rich dynamics generated and reconstructed in academic and research spaces in the Global South. In this study of networks of scientific collaboration, we showed some elements of analysis that allowed us to agree but also distance ourselves from those positions, through the analysis of a specific case where some types of link were identified that the mathematicians of the former USSR have built in and from Mexico.

We found that their collaborations are not precisely with colleagues located in their countries of origin (they are still connected with colleagues from former Soviet Union located in other parts of the world); rather they are with colleagues from the host country, followed by colleagues in the European Union. In such collaborations, Asia has become an emerging region of science links to be taken into account in future research and the 'incipient' collaborative networks identified through *Pajek* between Mexico and Brazil, are a starting point and opportunity to make an in-depth study on the relations between the actors and the relationship patterns that arise in the Global South; analysis that we have pending. Another type of link is what scientists maintain with colleagues and students in Mexico. It was found that the universities where most of their collaborations are held are those located in the knowledge centralized space in the country. We also found five institutions of the "periphery" of Mexican science where they have built links, especially with some of their former thesis students with whom they continue to maintain contact and participate in jointly organized events. The study of the collaborative networks of these scientists provides some elements of analysis that make it possible to visualize, and study in depth in the future this immigration in the context of the world capitalist re-realignment in which both regions (the former USSR and Latin America) have remained in the "periphery", redrawing the South-North one-way flows by presenting other ways of linking science.

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